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Edited by C. M. Campbell and E. F. Robertson

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PREFACE

We would like to thank Cambridge University Press for encouraging us to produce this new edition of the Proceedings of Groups St Andrews 1981. At the suggestion of Roger Astley of Cambridge University Press we have asked the four main speakers at the 1981 conference to provide brief addenda to their articles. We are delighted that they have all responded positively to this task. Three of the authors have provided their own new pages. The fourth article on ‘An elementary introduction to coset table methods in computational group theory’ has been prepared by us with our friend and collaborator George Havas after some helpful suggestions from Joachim Neubüser. We have also added a short article looking back at twenty-five years of Groups St Andrews conferences.

Although for the 1981 Proceedings we put all the references into a standard form, we have, twenty-five years later, adopted a more relaxed approach and have kept the refereeing style of the addenda as provided by the authors.

Thanks are also due to our colleague Martyn Quick for his help with the preparation of the additional material.

Colin M. Campbell
Edmund F. Robertson
St Andrews, August, 2006

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TWENTY-FIVE YEARS OF GROUPS ST ANDREWS CONFERENCES

COLIN M. CAMPBELL and EDMUND F. ROBERTSON

In 1979 we held a small meeting in St Andrews at which Joachim Neubüser from RWTH Aachen spoke on *Counterexamples to the class-breadth conjecture*. At this time we discussed the possibility of organising a much larger group theory meeting in St Andrews in 1981. Preliminary dates were suggested to fit the German school holidays. Indeed choosing dates for all the meetings has proved an interesting task: fitting in with the end of the English academic year, the start of the American academic year, the Galway races (Galway 1993), the Open University Summer School (Bath 1997), the Open Golf Championship (St Andrews 2005). For Groups 1981 we invited main speakers whose mathematical interests were close to our own. By chance, three of the four — Joachim Neubüser (RWTH Aachen), Seán Tobin (Galway), and Jim Wiegold (Cardiff) — had been friends from postgraduate days in Manchester. The fourth, Derek Robinson (Urbana), was originally from Montrose (visible on a good day across the Tay estuary from the Mathematical Institute in St Andrews). Despite our planning of the 1981 dates, the wedding of Prince Charles and Princess Diana was announced to take place during the period of the conference. Residences provided only packed lunches on the wedding day. However Jim Wiegold, the ‘Mathematical Prince of Wales’, provided our own star attraction! We had intended the conference to last a week but some participants wanted to stay in St Andrews for a further week. Thus began our style of a two-week conference, the main speakers giving lecture courses in the first week with a more informal seminar programme taking place in the second week.

During the 1981 conference, carried away by the excitement of the moment, we discussed, while we were driving participants round the Highlands (actually on a stop at Killin), holding another meeting in four years time. The 1985 meeting proved the largest of all the Groups St Andrews meetings with 366 participants from 43 countries. For this meeting we tried to make the topics broader to cover as much of group theory as possible. With this aim in mind we invited Seymour Bachmuth (Santa Barbara), Gilbert Baumslag (CUNY), Peter Neumann (Oxford), Jim Roseblade (Cambridge) and Jacques Tits (Paris) to be the main speakers. It is always a challenge to people to ask them what is wrong with the photograph of the main speakers, and ourselves, as it appears in the Conference Proceedings. (Clue: does it look better in a mirror?) Again, carried away by the vitality of the Conference, we announced another meeting to be held in 1989.

Following the 1985 conference we asked a number of the participants which group theorists they would like to see as main speakers for 1989. Taking their advice we invited Sandy Green (Warwick), Narain Gupta (Manitoba), Otto Kegel (Freiburg), Sasha Ol’shanskii (Moscow), and John Thompson (Cambridge). Typical of problems organisers have to face, there was a “heightening of tension” between the UK and the Soviet Union in the spring of 1989. Consulates were closed, as was

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the British Airways Office in Moscow. The Principal of St Andrews University, Professor Struther Arnott, wrote to his colleague, the Rector of Moscow State University, in an attempt to make Sasha Ol'shanskii's visit possible. It was a great surprise and pleasure when Sasha achieved what we thought was impossible at that time, and actually arrived in St Andrews. So many of the participants were, by this time, friends we were delighted to meet again. Indeed it was (and is) great to see so many people from so many different countries renewing friendships and mathematical contacts at our conferences.

After three conferences in St Andrews, we thought that a change of scene might be appropriate. We had enjoyed a very successful mathematical collaboration between RWTH Aachen, Galway and St Andrews (with an EU twinning grant for three twins!) and our Galway colleagues had (and still have) such a successful annual Group Theory meeting that we were happy to accept their invitation to hold Groups St Andrews 1993 in Galway. We now became part of an organising committee of five (us together with Ted Hurley, Seán Tobin and James Ward from Galway). The five organisers met at a Warwick conference in March 1991, and decided to invite as principal speakers Jon Alperin (Chicago), Michel Broué (Paris), Peter Kropholler (Queen Mary College, London), Alex Lubotzky (Hebrew University of Jerusalem) and Efim Zelmanov (Wisconsin-Madison). (We were especially delighted when Efim was awarded a Fields Medal exactly one year later at the 1994 ICM in Zurich.) We also invited our Aachen twin Joachim Neubüser to organise a GAP workshop at the 1993 conference. The workshop became effectively a fully-fledged parallel meeting throughout the second week, with over thirty hours of lectures by experts together with practical sessions. Another unusual feature of this conference was the setting aside of one day for a special programme of lectures to honour the 65th birthday of Karl Gruenberg (London), in recognition of his many contributions to group theory.

In 1989, at the conference, Geoff Smith (Bath) said that he would be interested in hosting a future Groups St Andrews meeting. At the 1993 conference Peter Neumann (Oxford) asked if Oxford might be considered as a venue for 1997. By this time, however, we had already accepted the invitation to hold the 1997 Conference in Bath, but it was agreed that Oxford would be the venue for 2001. For the Bath Conference Geoff Smith joined us on the organising committee. The main speakers for the 1997 conference were Laszlo Babai (Chicago), Martin Bridson (Oxford), Chris Brookes (Cambridge), Cheryl Praeger (Western Australia) and Aner Shalev (Hebrew University of Jerusalem). This time the second week featured two special days, a Burnside Day and a Lyndon Day, organised by Efim Zelmanov (now at Yale) and Chuck Miller III (Melbourne), respectively. An interesting innovation at this conference was twelve editions of *The Daily Group Theorist* providing details of lectures, seminars, the social programme, together with other items of interest.

The organizing committee for Groups St Andrews 2001 in Oxford consisted of the two of us together with Danny Groves (Merton, Oxford), Patrick Martineau (Wadham, Oxford), Peter Neumann (Queen's, Oxford), Geoff Smith (Bath), Brian Stewart (Exeter, Oxford) and Gabrielle Stoy (Lady Margaret Hall, Oxford). For the Oxford conference the main speakers were Marston Conder (Auckland), Persi

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Diaconis (Stanford), Peter Palfy (Eötvös Loránd, Budapest), Marcus du Sautoy (Cambridge), and Mike Vaughan-Lee (Christ Church, Oxford). In the second week there was a day of special lectures in celebration of Daniel Gorenstein coordinated by Richard Lyons (Rutgers) and a “Groups and Sets” day coordinated by Simon Thomas (Rutgers). Again the ~~The Daily Group Theorist~~ provided entertaining and informative reporting items such as “Punting tragedy”, “News from the Netherlands”, “Dancing in a group”, and “Editor in Bath... pictures follow”.

We realised that Groups 2005 would be the last of the series that we would organise before retiring so we made the decision to bring the conference ‘home’. Unlike the earlier St Andrews conferences we had an extended organising committee, being joined by Nick Gilbert (Heriot-Watt), Steve Linton (St Andrews), John O’Connor (St Andrews), Nik Ruskuc (St Andrews), and Geoff Smith (Bath). We also reverted to the format of the 1981 conference and put the whole programme into a week. The main speakers were Peter Cameron (Queen Mary, London), Slava Grigorchuk (Texas A&M), John Meakin (Nebraska-Lincoln) and Akos Seress (Ohio State). Additionally there were seven one-hour invited speakers together with an extensive programme of over a hundred seminars; a lot to fit into a week!

The seven conferences have contained a wide selection of social events. “Groups St Andrews tourism” has taken us to a variety of interesting and scenic venues in Scotland, Ireland, England and Wales. Bus trips have included Kellie Castle, Loch Earn and Loch Tay, Falkland Palace and Hill of Tarvit, Crathes Castle and Deeside, Loch Katrine and the Trossachs, House of Dun, Connemara and Kylemore Abbey, the Burren and the Cliffs of Moher, Tintern Abbey and Welsh Valleys, the Roman Baths in Bath, Salisbury Cathedral, Rufus Stone and the New Forest, Stonehenge, Wells Cathedral and the Cheddar Gorge, Blenheim Palace, Glamis Castle. We have been on boats on Loch Katrine, the Thames, and Galway Bay to the Aran Islands. There have also been: musical events with participants as the musicians, Scottish Country Dance evenings, barn dances, piano recitals, organ recitals, theatre trips, whisky tasting, putting, chess, walks along the Fife Coast, walks round Bath, walks round Oxford, and there would have been a cricket match in Bath but it was rained off. All these have provided opportunities for relaxation, but also opportunities to continue mathematical discussions. For example after the trip to Falkland Palace we collected from the buses several copies of the guidebook, each filled with fascinating group theory theorems. Conference dinners have taken place in David Russell Hall (old and new) in St Andrews, the Corrib Great Southern Galway, the Ardilaun House Hotel Galway, the Assembly Rooms in Bath (“a grand Georgian affair with chandeliers etc.”), Cumberwell Park Golf Club (in Bradford-on-Avon and not St Andrews!) and Lady Margaret Hall Oxford.

The twenty-five years since 1981 have been an important period in the development of group theory following the classification of finite simple groups. Although attempting wide coverage of group theory topics, we made a conscious decision for the early conferences not to have a lecture series devoted to the classification. Despite the intervening twenty-five years, the papers from the first conference are still proving influential and hence the appearance of this second edition of the Groups St Andrews 1981 Proceedings. The main speakers at this conference spoke on: *An*

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elementary introduction to coset table methods in computational group theory; Applications of cohomology to the theory of groups; Groups with exponent four; and The Schur multiplier: an elementary approach. The topics of the lectures given at the conferences show the development of group theory during the quarter century. This is illustrated by the themes of the main speakers at the last two conferences. At Groups St Andrews 2001 the lecture series were: *Group actions on graphs, maps and surfaces with maximum symmetry; An introduction to random walks on finite groups — character theory and geometry; Groups and Lattices; Zeta functions of groups and counting p -groups; and Lie methods in group theory*, and at Groups St Andrews 2005: *Aspects of infinite permutation groups; On self-similarity and branching in group theory; Interactions between group theory and semigroup theory; and Graphs, automorphisms, and product action.* The influence of the series of conferences is, we believe, illustrated by the fact that ‘Groups St Andrews’ is mentioned in 285 reviews in MathSciNet and over 1500 papers in a beta version of the Google Scholar search.

None of this would have been possible without the support of many people and organisations. Research students and colleagues have provided invaluable help in running each of the conferences. The British Council, the Edinburgh Mathematical Society, the London Mathematical Society, the Royal Society of London have provided grants, while the universities of St Andrews, Galway, Bath and Oxford have all contributed in financial and other ways to the success of the conferences. Of course the bulk of the funding has come from universities and other organisations worldwide that have supported the participation of the delegates.

We are grateful to Cambridge University Press, in particular to David Tranah and Roger Astley, for the care and expertise with which they have published the Proceedings. The Proceedings of each of the first six conferences have been published by CUP as numbers 71, 121, 159 & 160, 211 & 212, 260 & 261, 304 & 305 in the *London Mathematical Society Lecture Note Series*. The Proceedings of Groups St Andrews 2005 will again be published in two volumes in the same series. Additionally there was a special part (Volume 30 Part I) of the *Proceedings of the Edinburgh Mathematical Society* consisting of sixteen of the papers presented at Groups St Andrews 1985, together with an introduction.

We have enjoyed the twenty-five years of Groups St Andrews conferences and look forward to the continuation of the series. We hope to meet many of our friends at Groups St Andrews in Bath in August 2009.

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ORIGINAL INTRODUCTION

An international conference 'Groups - St. Andrews 1981' was held in the Mathematical Institute, University of St. Andrews during the period 25th July to 8th August 1981. The main topics of the conference: combinatorial group theory; infinite groups; general groups, finite or infinite; computational group theory are all well-represented in the survey and research articles that form these Proceedings. Four courses each providing a five-lecture survey, given by Joachim Neubüser, Derek Robinson, Sean Tobin and Jim Wiegold have been expanded, subsequently, into articles forming the first four chapters of the volume. Many of the themes in these chapters recur in the survey and research articles which form the second part of the volume.

Methods and techniques such as homology, geometrical methods and computer implementation of algorithms are used to obtain group theoretical results. Computational methods are surveyed in several articles in particular the major survey by Joachim Neubüser and find application in papers on Burnside groups and finite simple groups. In fact Burnside groups are discussed in two rather different papers, a survey of groups of exponent four by Sean Tobin and a major contribution to the exponent five case by Marshall Hall and Charles Sims. Derek Robinson exploits the way in which cohomology groups arise in group theory to establish some splitting and near-splitting theorems. Rudolf Beyl also uses homological techniques to discuss group extensions. The Schur multiplier which arises naturally in this context is given a 'nonhomological' treatment (and is called the Schur multiplier!) in a survey by Jim Wiegold.

Splitting results are also studied by Klaus Roggenkamp when he considers the splitting of the natural injection from a group to the group of units in its group ring. The structure and group-theoretical properties of the group of units of a group ring feature in another survey article. Presentations of groups are studied in many of the articles already described. Several other authors discuss groups with presentations of a specific type, for example small cancellation groups and one-relator groups.

The reader will find extensive bibliographies with many of the papers. Many open problems are also cited in the papers often with possible methods of attack. We hope that this not only makes the volume a useful record of the current state of the art but also points the way to future developments.

During the two weeks of the conference, group theory programmes on the Aberdeen Honeywell and the St. Andrews VAX were widely used by conference participants. The CAYLEY group theory package was demonstrated from the Queen Mary College computer via a link to the St. Andrews VAX. We would like to thank those in the University of St. Andrews Computing Laboratory who helped make these facilities available.

We would like to express our thanks for the assistance we received from our col-

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leagues in the Mathematical Institute and in particular John Howie, John O'Connor and Peter Williams. We thank the British Council for grants for two conference participants and the London Mathematical Society for their early pledge of financial support which enabled the conference to proceed. Our thanks are also given to the London Mathematical Society and Cambridge University Press for their help and encouragement in the preparation of this volume, and to Shiela Wilson for so willingly undertaking the daunting task of typing a volume of this length and for the high quality of the final typescript.

Our final thanks go to those who have contributed articles to this volume. We have edited these articles to produce some uniformity without, we hope, destroying individual styles. We will have introduced inevitably errors into the text. For these errors we take full responsibility.

Colin M. Campbell
Edmund F. Robertson
St Andrews, June 1982